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CORROSION AND WEAR DURING COMMINUTION
PART 5. GRINDING MODIFIERS

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PHYSICAL SCIENCES LABORATORY
CORROSION SECTION

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by
R.J. Brigham* and M.W. Kilpatrick**

ABSTRACT

Chemical additions to the ball mill which change the fineness of the grind of hematite ore by mechanical and electrochemical means are discussed. The mechanical (viscosity) effects are shown to be large with possible industrial significance while the electrochemical effects are small with only theoretical impact.

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LA CORROSION ET L'USURE PENDANT LE BROYAGE 5ieme PARTIE. DES MODIFICATERUS DU MEULAGE

par
R.J. Brigham* et M.W. Kilpatrick**

SOMMAIRE

Cette cinquième partie de l'étude sur la corrosion et l'usure pendant le broyage traite des produits chimiques qui, ajoutés au broyeur, varient, à l'aide de procédés mécaniques et électrochimiques, la grosseur du minerai d'hématite broyé. Les effets résultant du procédé mécanique (la viscosité) s'avèrent énormes et possiblement assez importants pour l'industrie, tandis que ceux obtenus par le procédé électrochimique sont négligeables et d'un intérêt théorique seulement.

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INTRODUCTION

Experimental investigations carried out in this laboratory as part of the Minerals Research Program Work Element MUI.I, Corrosion and Wear Control of Grinding Media, have defined two variable factors, corrosion and abrasion, which contribute to grinding media consumption. Other factors, to be discussed below may also be important. In this presentation, discussion will be limited to hematite ore.

a) Corrosion

In grinding hematite ore, the extent of corrosion has been defined and control methods developed. These include pH modification[1,3], oxygen content control[2] and inhibitor additions[3]. However, with high quality hard balls (Rc 65) the effect was lower than anticipated and the loss due to corrosion may amount to approximately 10%[4].

b) Abrasion

It has been clearly demonstrated that the abrasion rate depends upon chemical additions to the slurry and the extent of abrasion has been defined with several additives[1,4,5] and at different slurry densities[6]. Abrasion control methods are only partially understood[4] at the present time. Even with high quality hard balls the abrasion effect is larger than anticipated and, if inappropriate additions are made to the grinding mill, the abrasion rate can be significantly increased.

Further work is planned in this area to understand the abrasion phenomenon.

One other factor, in addition to corrosion and abrasion, must be considered in minimizing grinding media consumption. This factor is fineness of grind. If the capacity of a mill can be increased at the same wear rate of media, the consumption of balls per ton of ore is necessarily lower. Grinding modifiers which change the fineness of the grind are expected to have two effects: mechanical and electrochemical.

a) Mechanical

Klimpel and Manfroy[7] have shown that a change in slurry viscosity results in a change in the selection of ore particles for breakage. Reduced viscosity due either to a less dense pulp or a grinding aid at high pulp density resulted in a finer grind.

b) Electrochemical

Changes in slurry chemistry are expected to change the degree of ionic adsorption on ore particles and consequently the surface free energy of the ore. Ore particles with lower surface free energy which are selected for breakage would be expected to break into smaller daughter particles under the same impact than particles of higher surface free energy. This effect has been demonstrated by Frangiskos and Smith[8] for grinding quartz and limestone.

Consequently, it was decided to investigate grinding modifiers in at least a preliminary way to get a more complete picture of all the factors responsible for grinding media

consumption. The results presented below have such economic significance for the Canadian minerals industry that this report has been classed "CONFIDENTIAL". This author believes that an intensified research effort should be undertaken in this area.

EXPERIMENTAL

Batch grinding tests were carried out at room temperature in a laboratory-scale porcelain mill (5.3ℓ capacity) rotated at 70 rpm as rollers for 20 minutes. In all cases a charge of 1150g of -10 mesh hematite ore was wet ground by a 9080g charge of 2.54 cm diameter 52100 steel balls. Pulp densities of 59, 70, 79 and 85% solids were achieved by adding 800, 500, 300 and 200 ml of distilled water or solution, respectively, to the ore charge in the mill. After grinding, the total ore charge was washed with high pressure water on a 200 (Tyler) mesh screen to remove the slimes. The ore remaining on this screen was dried at 110°C and subjected to a screen analysis consisting of 35, 48, 65, 100, 150 and 200 (Tyler) mesh screens. This nest of screens was shaken for 15 minutes on a Ro-tap machine. The results were plotted as cumulative percentage passing a given mesh on probability paper for the 35, 48, 65 and 100 mesh screens. Because the whole sample was screened, only the 35, 48 and 65 mesh screens were within the loading limit of 100g recommended by Taggart[9] for screens with openings >250 microns. However, results for the 100 mesh screen were included although they may be suspect because the recommended loading of 50g for screens of

opening <250 micron was exceeded by a factor of approximately 2 in most cases. Results obtained with the 150 and 200 mesh screens were disregarded because of gross overloading which tended concentrate the data at one value as an artifact of the way in which the test was carried out.

RESULTS AND DISCUSSION

Of the two factors mentioned above which may lead to changes in the fineness of grind, the mechanical effects have been found to be much more significant than the electrochemical effects and will be discussed first.

a) Mechanical Effects

Klimpel and Manfroy[7] observed that the fineness of the grind increases with decreasing pulp density and that certain unspecified grinding aids have the same effect in high density slurries. For example, they saw no effect of grinding aids with Taconite ore at 82% solids but the effect became progressively larger at 84 and 86% solids. They attributed the effects to changes in viscosity. Although Klimpel and Manfroy carried out their experiments at constant total volume and this work was carried out at constant weight of ore, similar trends have been observed. Using hematite ore, minimal changes in fineness of grind were observed with any addition at 59 and 79% solids while the results at 85% solids are shown in Figure 1. If the grind obtained in distilled water is used as a standard, it can be seen that the addition of 1% "Liqui-nox", a laboratory detergent and wetting agent, to the distilled water made a

substantial improvement in the fineness of the grind. For example, approximately 77% of the ore passed 100 mesh when ground in H_2O while >90% passed when ground in H_2O plus 1% soap. Similarly at 65 mesh, 94.5 and 99% of the ore passed, respectively. This increase in fineness is equal to approximately one mesh size as shown in Figure 1.

b) Electrochemical Effect

The effect of adding surface active chemical to the mill on the fineness of the grind is shown in Figure 2 for slurry of 79% solids. Again using distilled water as the standard grinding medium, it can be seen that the addition of 1% $FeNH_4(SO_4)_2$ had a small but real effect on the fineness of the grind. However, the addition of 0.2% NaOH, 0.5% CaO or 1% K_2CrO_7 gave results identical to the standard while a slurry made from distilled water plus 2g/ℓ Na_2SO_4 and 0.2g/ℓ NaCl gave a marginally coarser grind. Changes of approximately the same magnitude were observed at 59 and 70% solids with a number of surface active additions.

For comparison with the results in Figure 1, data for grinding in H_2O + $SO_4^{=}/C\ell^{-}$ + 1% soap is also included in Figure 2 at 79% solids. Although the mechanical (viscosity) effect at 79% solids is larger than the electrochemical effects, it is much smaller than observed in 85% solid pulp as shown in Figure 1.

SUMMARY

These data lead to two conclusions. Firstly, the electrochemical effect of surface active reagents is small and of little practical significance (but great theoretical interest). Secondly, the mechanical (viscosity) effect of grinding aids is large and of great practical importance. The data presented here show a significant increase in fineness of grind and as yet the effect has not been optimized with respect to % solids, pH, soap concentration or other soap-related chemicals. Although other data[5,6] indicate that ball wear increases with the use of this grinding aid at this concentration, an increase in through-put of $4\sqrt{2}$ or 19% (assuming an increased fineness of one screen size) in an industrial mill would lower the fixed costs per ton of ore ground by a significant amount.

The development and optimization of grinding aids for hematite and siliceous ores could have a significant impact on energy and materials conservation (and consequently on costs) in the Canadian minerals industry.

CONCLUSION

I recommend to CANMET management that the implications of grinding aids be given serious consideration.

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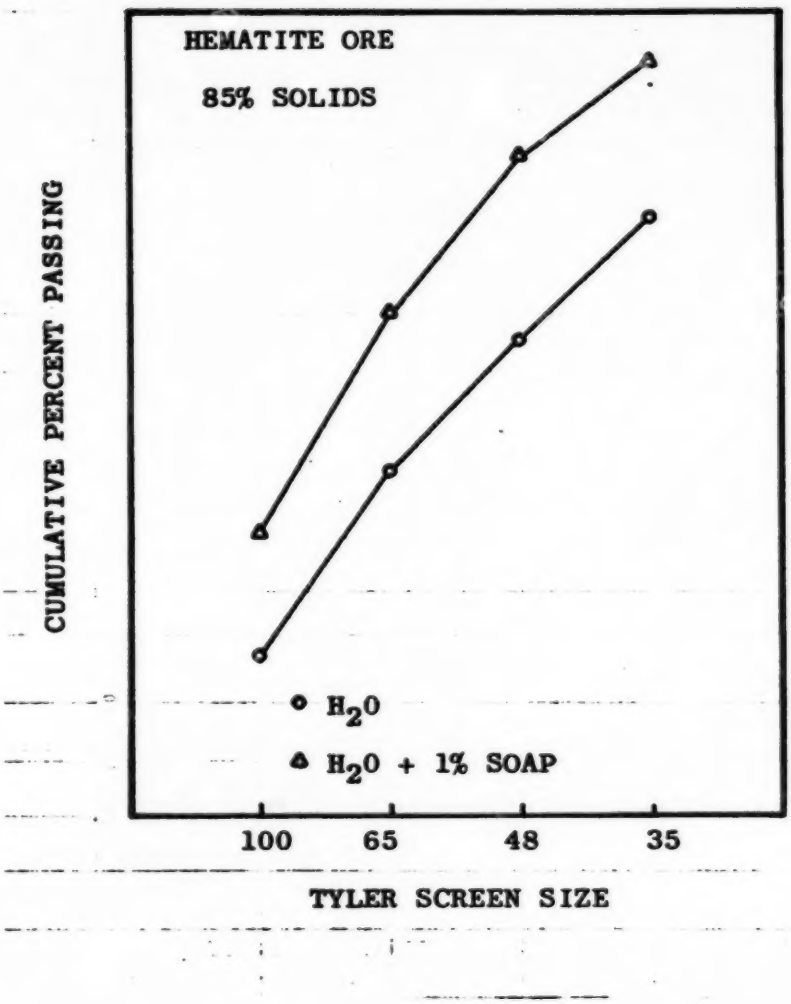

Figure 1. Screen analysis of hematite ore (85% solids) after a 20 minute grind with and without a grinding modifier which alters mechanical (viscosity) properties.

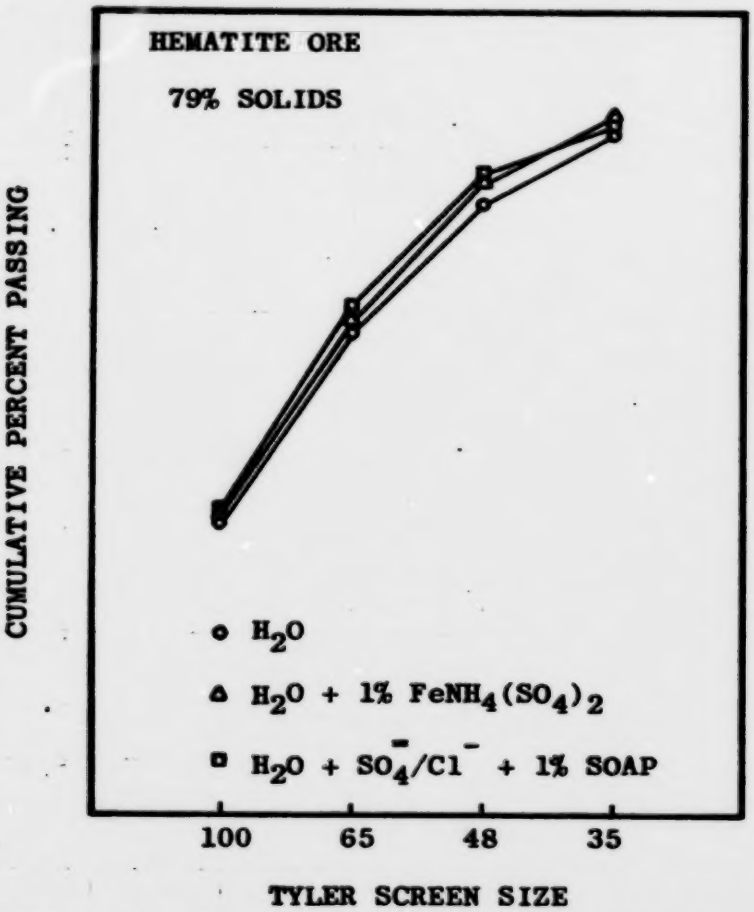

Figure 2. Screen analysis of hematite ore (79% solids) after a 20 minute grind with and without a grinding modifier which alters mechanical properties and one which alters electrochemical properties.